the meantime in the vicinity of Washington there had been material settlement of the snow. The measurements by Kalitin over bare ground in April and May give much higher values than are given in Table 2, flight No. 2, and this is also true of similar measurements by Ångström using a pyrheliometer (MONTHLY WEATHER REVIEW, November, 1926, vol. 54, p. 453). In explanation of these differences it should be remembered that the Richardson photometer measures the vertical reflection from an area of small angular extent immediately below it, while the pyrheliometer employed by Kalitin and Ångström measures the light received from a full hemisphere. Since newly fallen snow gives an almost perfect matt-surface, it has the same brightness from whatever angle it is viewed. The vertical reflection is the same as the reflection from various angles of incidence. This is not the case with water surfaces, plowed ground surfaces or sod surfaces. The first named becomes nearly a perfect reflector at low angles of incidence, as compared with the low reflection obtained at normal incidence. Fields of growing grain or grass present a deeply pitted surface with the bottoms of the pits poorly illuminated. When viewed at normal incidence it is principally the illumination from the bottom of these pits that is measured, while as the angle of incidence increases the reflecting surfaces present an increasing percentage of leaf surface. For this reason measurements with the pyrheliometer give values of reflection from sod surfaces approaching in value the reflecting power of leaf surfaces as measured by Coblentz and others.

RAINFALL CATCH AS AFFECTED BY DIFFERENT DEPTHS OF FUNNELS IN THE RAIN GAGE

By BENJAMIN C. KADEL

[Weather Bureau, Washington, April 18, 1930]

The standard 8-inch rain gage of the United States Weather Bureau is equipped with a collecting funnel having a vertical wall 2¼ inches deep to the sloping part, then a slope angle of 41½° below the horizontal to the outlet.

From time to time honest doubts as to the sufficiency of the depth of this funnel have been communicated to the instrument division of the Weather Bureau, and in an effort to obtain some facts several comparisons were carried on:

The first comparison was voluntarily undertaken by one of these honest doubters, Mr. C. A. Hurlbutt, cooperative observer, Elk Creek station, Pine Grove, Colo., who was provided by the instrument division with a second gage exactly like his standard, but with the vertical wall of the funnel 6 inches deep as compared with the 2¼-inch standard. Mr. Hurlbutt made readings of both gages daily, May to October, 1923. The total catch in the standard funnel was 23.59 inches and in the funnel with 6-inch wall 23.97, an increase of 1.4 per cent. Of the 97 comparisons made, 78 showed exact agreement between the two gages, 7 showed 0.01 inch more caught in the deeper funnel, 7 showed 0.02 inch more, 1 showed 0.03 inch more, 1 showed 0.05 inch more, while one instance showed 0.03 inch less.

Differences for each rain can not well be expressed in percentages, and it seems needful for a complete understanding to present, as Table I, the tabulated measurements as Mr. Hurlbutt reported them. Wind velocity was not recorded:

Through the cooperation of Dr. Oliver L. Fassig in charge of the San Juan, P. R., station of the Weather Bureau and his assistants a more extended set of comparisons was carried out on the grounds of the San Juan Weather Bureau station. Two standard 8-inch gages, one with vertical wall of funnel 2¼ inches deep, the other with wall 6 inches deep were exposed side by side. Detailed measurements are presented in Table II.

The total catch in the 2¼-inch funnel was 47.41 inches and in the 6-inch funnel 47.96 inches, or 1⅛ per cent more. Of the 145 measurements made, 77 showed exact agreement, 23 showed 0.01 inch more for the deeper funnel, 12 showed 0.02 inch more, 5 showed 0.03 inch more, and 1 showed 0.06 inch more, 20 showed 0.01 inch less, 2 showed 0.02 inch less, and 1 showed 0.04 inch less.

TABLE 1.—*Daily catch of rainfall (inches) two 8-inch gages equipped with 2¼-inch and 6-inch funnels, respectively. Elk Creek Station, Pine Grove, Colo.*

	May		June		July		August		September		October	
	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches
1					0.37	0.38	0.75	0.75	0.02	0.02	0.10	0.12
2					.05	.05					.08	.09
3	0.03	0.03	0.20	0.20	.02	.02	.01	.01			.23	.25
4			.62	.62	.01	.01	.11	.13			.64	.67
5	.09	.09	.22	.22			.05	.05	.02	.02	.06	.08
6	.03	.03	.07	.07			.25	.25				
7	.02	.02	.05	.05	.37	.37	.81	.85				
8			.65	.65	.53	.55	.36	.36				
9			2.62	2.62			.26	.26				
10			.10	.10	.21	.21	.05	.05				
11	.04	.04					.45	.45	.02	.02		
12	.08	.08	.02	.02	.30	.30	.32	.32			.68	.68
13	.10	.10							.07	.07	.08	.09
14	.29	.31			.36	.36	.15	.15	.10	.10		
15	.23	.23			.72	.72	.55	.55				
16	.01	.01	.20	.20	1.25	1.30	.34	.34	.03	.03		
17	.03	.03			.54	.54	.25	.27	.12	.12		
18							.04	.04	.43	.47		
19					.29	.29	.42	.43			.01	.01
20	.01	.01			.06	.06	.20	.20				
21	.01	.01	.13	.13	.36	.36	.16	.16				
22	.35	.32					.18	.18				
23	.07	.07					.55	.55	.20	.21	.23	.23
24							.05	.05			1.28	1.28
25	.17	.17			.06	.06	.07	.07			.14	.14
26					.53	.54						
27					.95	.96	.01	.01				
28					.08	.08			.21	.21		
29											.05	.05
30									.04	.04		
31							.06	.06				
Sums	1.56	1.55	3.68	3.68	7.06	7.16	6.45	6.54	1.26	1.31	3.58	3.69

TABLE 2.—*Daily catch of rainfall (inches) two 8-inch gages equipped with 2¼-inch and 6-inch funnels, respectively. San Juan, P. R., May 6, 1924, to March 23, 1925*

	May		June		July		August		September	
	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches
1							0.04	0.04		
2					0.21	0.21	.24	.24		
3					.04	.04				
4					1.22	1.24				
5			0.11	0.11	.08	.08				
6	0.10	0.10			1.23	1.23	.02	.02		
7			.12	.11	.98	.98				
8			.07	.07						
9			.18	.18						
10	.31	.32	.33	.33						
11	1.72	1.78			.06	.06				
12	.33	.32	1.21	1.21	.01	.01				
13	.06	.07	.08	.08	.18	.18				
14	.03	.04	.06	.06	.09	.09				
15	.11	.12								
16	.07	.07								
17	.53	.53	.06	.06						
18	.08	.08								
19	.15	.15	.01	.01						
20	.15	.15			.13	.13				
21			.69	.67	.28	.28				
22			1.66	1.62	1.18	1.19				
23			.14	.15					1.96	2.00
24					.07	.07				
25	.04	.04	.36	.34	.07	.07				
26	.03	.03	.15	.15						
27	.06	.06	.04	.04	.03	.03	.42	.44		
28	.12	.12	.02	.02	.24	.26				
29	.21	.21	.07	.06						
30	.10	.10	.09	.08	.21	.21				
31										
Sums	4.20	4.29	5.45	5.35	6.31	6.36	.72	.74	1.96	2.00

	October		November		December		January		February		March	
	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches
1			1.94	1.93			0.37	0.40			0.22	0.22
2			.15	.15			.12	.13			.02	.03
3					0.41	0.40	.10	.11	0.01	0.01		
4					.25	.25	.36	.36				
5	0.87	0.89	.63	.63	.10	.10	.02	.02				
6	.20	.20	.02	.02	.29	.28	.45	.45	.05	.04		
7							.04	.04			.01	.01
8							.06	.06	.01	.01		
9									.30	.30	.01	.01
10							.36	.37	.94	.98	.06	.05
11			1.21	1.20								
12												
13					.73	.74					.65	.65
14			1.40	1.40					.60	.62	.04	.04
15			.20	.20	.24	.24			.05	.05		
16			.32	.31	.34	.33	.28	.30	.37	.39		
17					.45	.47	.28	.29	.50	.53	.05	.06
18			1.01	1.05	.59	.62			.60	.61	.06	.06
19					.33	.36			.08	.09	.10	.09
20			1.46	1.45	.11	.13	.05	.05	.04	.04	.04	.03
21			2.46	2.50	.29	.31					.08	.08
22			.32	.32	.05	.06	.12	.11	.20	.21	.05	.06
23					.02	.02	.03	.02	.02	.02	.05	.05
24			.31	.31	1.03	1.07			.10	.10		
25					.19	.20						
26					.72	.74	.02	.02				
27					.16	.17	.12	.12				
28					.64	.63						
29					.29	.30	.22	.23				
30					.12	.14	.03	.02				
31					.56	.55	.01	.01				
Sums	1.07	1.09	11.43	11.47	7.91	8.11	3.04	3.11	3.87	4.00	1.44	1.44

A recording anemometer in operation at San Juan makes possible examination of the catch as affected by wind. On nine occasions during which maximum winds 35 to 42 miles an hour were recorded, the catch was 3.55 inches and 3.62 inches, respectively, an increase of 2 per cent for the deep funnel. On 21 occasions with maximum winds 30 to 34 miles an hour, the catch was 5.18 and 5.54, respectively, an increase of less than 7 per cent.

Presentation of all these details is hardly warranted, but Table 3 shows that in moderately windy weather the advantage of the deeper funnel is not completely established. Two occasions, February 16 and 17, show an advantage for the deeper funnel, but the total amount of rainfall is not large, nor are these two occurrences considered conclusive evidence.

TABLE 3.—*Advantage of deeper funnel not completely established*

	Wind		Rainfall, inches		Per cent
	24 hours, miles	Maximum miles an hour	2¼-inch funnel	6-inch funnel	
May 11, 1924	253	15	1.72	1.78	+2
June 22, 1924	206	20	1.66	1.62	−2
Jan. 1, 1925	359	32	.37	.40	+8
Feb. 16, 1925	620	33	.37	.39	+5
Feb. 17, 1925	521	31	.50	.53	+6
			4.62	4.72	+2⅙

The San Juan comparisons include also measurements of the catch in two gages 12 inches in diameter, one being the tipping gage employed by the Weather Bureau for automatic record purposes and equipped with a funnel with rim 3 inches deep, sloping down 45° to the outlet; the other differing only in depth of funnel, which was 8 inches instead of 3. The catch in these two gages is shown in Table 4, to be in close agreement throughout the period, some of the monthly totals being the same for both gages, and the totals for the entire period differing by only six-tenths of 1 per cent. Reference to the individual values, not here presented, show the usual day-to-day differences.

TABLE 4.—*Catch of rainfall, San Juan, P. R.*

1924–1925	12-inch gages		Total	Per cent
	3-inch rim	8-inch rim		
May 6–31	4.17	4.21	+.04	+1
June	5.37	5.35	−.02	0
July	6.33	6.36	+.03	0
August	0.73	0.74	+.01	+1
September	2.00	1.98	−.02	−1
October	1.08	1.08	0	0
November	11.30	11.30	0	0
December	7.95	7.85	−.10	−1
January	2.97	2.89	−.08	−3
February	3.86	3.77	−.09	−2
Mar. 1–24	1.36	1.30	−.06	+4
	47.12	46.83	−.29	−0.6

Recognizing well known uncertainties attending the collection of rainfall, the conclusions to be drawn from these experiments may be stated as follows:

1. Increasing the 3-inch depth of the funnel of the 12-inch gage did not increase the amount of rainfall collected.

2. Increasing the 2¼-inch depth of the funnel of the 8-inch gage increased the amount collected by a little more than 1 per cent, a value within the limits of error.

3. There is no sufficient warrant in the showing made for correction of existing records made with either of the two gages (over 40 years), nor for recommending any change in United States Weather Bureau gages.

4. In the design of a new pattern rain gage the depth of funnel should be somewhat greater than 2¼ inches but need not exceed 3 inches.

It is known that a shallow funnel gage was discontinued many years ago in favor of the present form.